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The Use of ARIMA Models in Seasonal Adjustment

–A Comparative Study of Census X–11, X–11 ARIMA and Burman's Signal Extraction Method–

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Abstract: This paper compares the traditional Census X–11 method for seasonal adjustment with two recent alternative methods using ARIMA models, viz. X–11 ARIMA and Burman's signal extraction method. No strong preference results for one of these methods when applied to a number of macro-economic time series for the Netherlands.

1 Introduction

The comparative study of seasonal adjustment by *Fase, Koning* and *Volgenant* showed the Census X–11 method to be among the best of nine adjustment methods tested. This method has been used since by the Netherlands Bank for seasonal adjustment of a large number of macro-economic and financial data.

The fast evolution of time series analysis in the last decade has now prompted a reconsideration of this choice. *Box* and *Jenkins'* ARIMA models provide an adequate description of seasonal movements in time series and, therefore, these models can be used in seasonal adjustment. First, they may be used to modify and, hopefully, improve the Census X–11 method. Second, it is conceivable to decompose a time series according to its ARIMA model into a seasonal and a non-seasonal component.

This paper presents an empirical comparison between the Census X–11 method and two alternatives, viz. the X–11 ARIMA method developed by *Dagum* [1975] and *Burman's* signal extraction method. X–11 ARIMA is a Census X–11 modification, while Burman's method is based on decomposition of ARIMA models. The X–11 ARIMA method has already been tested extensively [see e.g. *Dagum*, 1978; *Dagum/Morry; Kuiper*] and is used in practice, while the decomposition methods using ARIMA models are still on the eve of leaving the laboratory. The Burman method is considered here because this method was operational and its computer program available to us at the start of this research project.

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Our study explicitly aims at investigating the alternative correction methods from the practioners' point of view. Therefore, no theoretical considerations which make one of the methods particularly suitable in specific cases, are taken into account. The paper, by way of comparing the alternative methods like software packages, shows the performance of these methods enabling prospective users to select one of them for general use.

Both X–11 ARIMA and Burman's signal extraction method apply ARIMA models of the time series to be adjusted. However, the Box and Jenkins identification procedure does not always produce a unique model for a time series, but often yields several alternatives between which it is difficult to discriminate. This study investigates the sensitivity of the seasonal adjustment methods to the choice of the ARIMA model.

An advantage of using ARIMA models for seasonal adjustment is that they are identified for each time series individually and hence may vary along with the typical data generating process that has produced the time series. For that reason, *Bell* and *Hillmer*, a priori prefer model based correction methods. In principle, Census X–11 employs the same filter for each series. *Cleveland* and *Tiao* demonstrated that this filter can be interpreted as a specific ARIMA model. In other words, Census X–11 applies the same ARIMA model for each series [see also *Burridge/Wallis*].

A disadvantage of seasonal adjustment using ARIMA models is that constructing ARIMA models is still a rather labour-intensive job. Such an adjustment is therefore not suitable for large numbers of series unless the identification of the models mechanized. Therefore, the ARIMA model based correction methods generally include automatic selection procedures. However, in our opinion, no satisfactory solution has yet been found to identify ARIMA models in a mechanical way. Since our study confines itself to macro-economic variables which are of great relevance to the Bank's economic and monetary analysis, in this case the drawback of incomplete mechanization does not hold.

The organization of the paper is as follows. Section 2 discusses the adjustment methods investigated in this study and shows the technical specification and limitations of the software. Section 3 gives the criteria of comparison. Section 4 presents the characteristics of the ARIMA models. Section 5 shows how these ARIMA models were used in making the seasonal adjustment, while section 6 discusses the results on the basis of the criteria of comparison. Finally, section 7 gives the conclusions.

2 Methods of Adjustment

The Census X–11 method [see *Shiskin/Young/Musgrave*] separates the trend-cycle component of a time series from the random and seasonal components by repeated application of weighted moving averages. Census X–11 enjoys a worldwide popularity as a seasonal adjustment method mainly because of the wide applicability and flexibility with which shifts in the seasonal pattern can be described. A disadvantage, however, is that addition of fresh data often leads to a substantial revision of the most recent adjustments. This is due to the use of asymmetrical weights in the moving averages at the end of the observation period. A number of procedures have been designed to obviate this drawback [see, e.g., *Akaike; Pierce*, 1980; *Pierce/Cleveland; Kenny/Durbin; Wallis*]. The X–11 ARIMA method circumvents the problem by using symmetrical weights instead of asymmetrical weights for each observation. To that end, the series is extrapolated by means of ARIMA forecasts.

Apart from the modifications of Census X–11 using time series analysis a number of seasonal adjustment methods exist that are entirely based on time series models. [see e.g., *De Vos; Pierce*, 1976; *Hillmer; Hillmer/Tiao; Box/Hillmer/Tiao; Bourdeau de Fontenay; Beveridge/Nelson; Pierce/Grupe/Cleveland*]. This study considers *Burman's* signal extraction method as an operational example of such a method of seasonal adjustment. This method decomposes the spectrum of an ARIMA model into a trend, a seasonal and an irregular part. These three parts of the spectrum define linear filters which are applied to generate estimates of the three corresponding components of the time series. The decomposition of the spectrum, however, is not unique and requires additional assumptions. The main assumption is that the seasonal adjustment should extract as little variation as possible from the original time series. This is the reason why Burman calls his method Minimum Seasonal Extraction (abbreviated to MSX, since MSE is already in use).

Both the X–11 ARIMA computer program, which was made available to us by Statistics Canada, and the program which has been developed at the Bank of England for Burman's signal extraction method (MSX) are subject to certain constraints on the order of the ARIMA models. These constraints are listed in Table 1 for an ARIMA $(p, d, q) \times (P, D. Q)_s$ model.

Table 1. Constraints on ARIMA models in computer programs X–11 ARIMA and MSX

	number of parameters p	d	q	P	D	Q	order of parameters
X-11 ARIMA	≤ 4	≤ 4	≤ 4	≤ 4	≤ 4	≤ 4	nc
MSX	≤ 3	nc	≤ 3	≤ 2	≤ 2	≤ 2	≤ 3

Explanatory note: nc means no constraints.

The table shows that the MSX program is subject to the most stringent constraints. These constraints restrict the identification of the ARIMA models in this study.

3 Time Series and Criteria Used in the Comparison

3.1 Time Series

A number of monthly and quarterly macro-economic time series, which play a major role in the Netherlands Bank's analysis, are selected in order to serve as a yardstick for comparison of the respective seasonal adjustment methods. There are 15 monthly and 19 quarterly series. Series 1–3 were already used by *Fase* et al. in the comparative study. Series 4–7 comprise the counterparts of the money supply on the consolidated balance sheet of the money-creating institutions and add up to series 3.

Den Butter and *Hogeweg* investigated the seasonal adjustment of this set of series, paying special attention to the residual entry between the sum of the seasonally adjusted series 4–7 and the seasonally adjusted total of series 3. Series 8 is a simulated series, where consequently the seasonal component is known. This series has a continuously increasing trend-cycle component with a cyclical movement of a period of 8 years, a changing seasonal pattern and an irregular component drawn at random from a lognormal distribution. The series has also been used by *Fase* et al.. The other monthly and the quarterly series are drawn from various data bases of the Bank. The monthly series consist of 157 (1967: 12–1980: 12) or 169 (1967: 12–1981: 12) observations and the quarterly series comprise 48 (1970: I–1981: IV) observations. For a description and source of the data see Appendix A.

All series that do not contain negative values are adjusted using the multiplicative variant of the Census X–11 method. This is in conformity with common practice at the Bank and is based on previous investigation of a number of series considered in this study. Accordingly, the ARIMA models, used by the X–11 ARIMA and the MSX adjustment method, have been estimated for the logarithm of the series. Of course, when negative values occur, the additive variant of Census X–11 is selected and no logarithms are taken in the ARIMA models. For the sake of simplicity the option for a Box–Cox transformation, provided by the X–11 ARIMA program, has not been used, albeit that the use of this transformation is often advocated for specific series [e.g. unemployment, see *Newbold/Thury*, 1984a, b; *De Vos*].

3.2 Criteria of Comparison

The study by *Fase* et al. provides the criteria by which the quality of the various adjustment methods can be judged[2]. The criteria are (see Appendix *B* for the formulas):

(a) Average absolute percentage change
This criterion indicates the smoothness of the seasonally adjusted series relative to the original series.

(b) Orthogonality
This criterion measures the correlation between the seasonal component and the seasonally adjusted series.

(c) Idempotency
This criterion reveals residual seasonal movements in the seasonally adjusted series. A seasonal adjustment method is idempotent if application of that method to the seasonally adjusted series yields exactly the same series.

[2] *De Vos* rightly observes that adjustment methods may be constructed which completely satisfy most of these criteria, yet produce no meaningful seasonal adjustment. The study of *Fase* et al. as well as this study do not consider such singular adjustment methods, but only methods wich seek to satisfy the general notion of seasonal adjustment. In that case this collection of criteria, which admittedly can be extended at will, offers a good opportunity to compare the various adjustment methods.

(d) Residual noise
The Box-Pierce or portmanteau test checks whether the noise component contains a residual pattern.

(e) Stability
This criterion shows to what extent the seasonally adjusted series changes when observations are added. The usefulness of seasonal adjustment is considerably reduced if recent figures, which are most important to policy analysis, are constantly subject to change. Since X–11 ARIMA seeks to be an improvement of Census X–11 in this very respect, our study pays ample attention to stability.

In addition to the above criteria, which have been applied to all series, the simulated series have been checked for:

(f) Estimation errors
In the case of a simulated series we know the "true" seasonally adjusted series, which enables calculation of the estimation errors when using the various adjustment methods.

Finally the paper investigates the problem of the residual entry [see *Den Butter/Hogeweg*] by measuring:

(g) Seasonality in the residual entry.
If such residual seasonality is small or absent, there will be a tendency to use the sum of the seasonally adjusted component series as the seasonally adjusted total series, thus avoiding the problem of the residual entry.

4 The ARIMA Models

The application of Burman's signal extraction method requires identification of the ARIMA model for the series to be adjusted. Such an identification may also be given as input for the X–11 ARIMA program. In the case the user provides no model identification, the latter program selects its own identification from a set of three alternatives.

In order to assess the sensitivity of the adjustment methods for the model choice we have, for all series of this study, identified and estimated ARIMA models according to the *Box* and *Jenkins* procedure. This is a common statistical technique and, although it contains judgmental elements, can be done by statistical assistants. The identification results are presented in the first column of Table 2. Deliberately, all models meet the constraints on the parameters as reported in Table 1 for the X–11 ARIMA program. These constraints only prohibit the identification of an adequate ARIMA model for three series, in so far as the portmanteau test indicates that the residuals of these models are not white noise. The results of Table 2 show that the seasonality of the series requires seasonal differencing for almost all series, while in the majority of the cases a normal difference had to be taken as well in order to obtain a stationary series. Moreover most models include a seasonal moving average parameter which also captures seasonal movements.

Table 2. Identification of ARIMA models

	own identification	identification by X-11 ARIMA	identification in MSX
Monthly series			
Output of manufacturing industry	$(2,1,0)x(0,1,1)_{12}$	no model	$(2,1,0)x(0,1,1)_{12}$
Male labour reserve	$(2,1,0)x(0,1,1)_{12}$ *	no model	$(2,1,0)x(0,1,1)_{12}$
Public authority floating debt	$(0,1,3)x(0,1,0)_{12}$ *	no model	$(1,1,0)x(0,1,1)_{12}$ o
Net money creating operations	$(2,1,0)x(0,1,1)_{12}$	$(0,2,2)x(0,1,1)_{12}$	$(2,1,0)x(0,1,1)_{12}$
Net foreign assets	$(2,1,0)x(0,1,1)_{12}$	no model	$(2,1,0)x(0,1,1)_{12}$
Miscellaneous items (net)	$(0,1,1)x(0,1,1)_{12}$	$(0,1,1)x(0,1,1)_{12}$	$(0,1,1)x(0,1,1)_{12}$
Money supply (M2)	$(1,1,0)x(0,1,1)_{12}$	no model	$(1,1,0)x(0,1,1)_{12}$
Simulated series	$(2,1,0)x(0,1,1)_{12}$ *	no model	$(2,1,0)x(0,1,1)_{12}$
Notes and coin	$(0,1,0)x(0,1,1)_{12}$	$(0,2,2)x(0,1,1)_{12}$	$(0,1,0)x(0,1,1)_{12}$
Demand deposits	$(4,1,0)x(0,1,1)_{12}$	no model	$(3,1,0)x(0,1,1)_{12}$
Time deposits	$(1,1,0)x(1,0,1)_{12}$	no model	$(1,1,0)x(1,0,0)_{12}$ o
Savings deposits with savings banks	$(0,1,1)x(0,1,1)_{12}$	$(0,1,1)x(0,1,1)_{12}$	$(0,1,1)x(0,1,1)_{12}$
Cost of living index	$(1,1,0)x(0,1,1)_{12}$	no model	$(1,1,0)x(0,1,1)_{12}$
Unemployment in industry (excl. construction)	$(2,1,2)x(0,1,1)_{12}$	$(2,1,2)x(0,1,1)_{12}$	$(0,2,2)x(0,1,1)_{12}$ o
Unemployment in construction industry	$(1,1,1)x(0,1,1)_{12}$	no model	$(1,1,1)x(0,1,1)_{12}$
Quarterly series			
Nominal GNP	$(0,1,1)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$
National expenditure (value)	$(0,1,0)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,0)x(0,1,1)_4$
Industrial output	$(1,0,0)x(0,1,1)_4$	$(0,2,2)x(0,1,1)_4$	$(1,0,0)x(0,1,1)_4$
Total taxes	$(0,1,1)x(0,1,1)_4$	$(0,2,2)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$
Interest charges on public debt	$(1,0,0)x(0,1,0)_4$	$(0,1,1)x(0,1,1)_4$	$(1,0,0)x(0,1,0)_4$
Public auth. fin. deficit on a transactions basis +	$(0,1,2)x(0,1,1)_4$	no model	$(0,1,2)x(0,1,0)_4$
Public auth. fin. deficit on a cash basis +	$(1,0,0)x(0,1,0)_4$	no model	$(1,0,0)x(0,1,0)_4$
Labour supply	$(0,1,0)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,0)x(0,1,1)_4$
Number of workers in man-years +	$(1,1,0)x(0,1,1)_4$	$(0,2,2)x(0,1,1)_4$	$(1,1,0)x(0,1,1)_4$
Total unemployment	$(1,1,0)x(0,1,0)_4$	no model	$(1,1,0)x(0,1,0)_4$
Total renumeration per industrial worker adjusted for absence due to sickness	$(0,1,0)x(0,1,1)_4$	no model	$(0,1,0)x(0,1,1)_4$
Volume of investments (excl. ships and aircraft) +	$(0,1,2)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,2)x(0,1,0)_4$
Domestic money supply	$(0,1,2)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,2)x(0,1,1)_4$
Changes in short-term bank lending +	$(1,0,0)x(0,1,1)_4$	no model	$(1,0,0)x(0,1,1)_4$
Net long-term operations of banks +	$(0,0,1)x(0,0,0)_4$	no model	$(0,0,1)x(0,1,0)_4$ o
Liquidity creation on behalf of public authorities +	$(0,0,2)x(0,1,1)_4$	no model	$(0,0,2)x(0,1,1)_4$
Financial assets of private sector	$(0,1,0)x(0,1,1)_4$	$(0,2,2)x(0,1,1)_4$	$(0,1,0)x(0,1,1)_4$
Exports	$(0,1,0)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,1)x(0,1,0)_4$
Imports	$(0,1,0)x(0,1,1)_4$	$(0,1,1)x(0,1,1)_4$	$(0,1,0)x(0,1,1)_4$

Explanatory notes:
- In an ARIMA-model $(p,d,q)x(P,D,Q)_s$, p is the number of autoregressive parameters, d the number of differences, q the number of moving average parameters, P the number of seasonal autoregressive parameters, D the number of seasonal differences and Q the number of seasonal moving average parameters. s indicates the period of seasonality.
- no model means that the automatic identification of X-11-ARIMA yields no solution.
- a * means that the residuals of the estimated ARIMA-model in our own identification are no white noise.
- a o means that the MSX-program rejected our own identification of the ARIMA-model.
- a + means that no logarithm is taken.

The second column of Table 2 presents the characteristics of the ARIMA models that have been selected automatically by the X–11 ARIMA program. The automatic identification often differs considerably from our own identification of the models. Moreover, if the program is unable to find an adequate model according to specific criteria with respect to the portmanteau test, the size of the average absolute error and overdifferencing, it will not perform seasonal adjustment. These events are indicated by 'no model' in the table. This happens for the monthly series in 10 out of 15 cases and for the quarterly series in 7 out of 19 cases. For three series (monthly simulated and cost of living index series and quarterly series for total renumeration per industrial worker) overdifferencing prevents the program from selecting a model. This is remarkable as our own identification of these series contains, like two of the three models implicit in X–11 ARIMA, both a normal and a seasonal difference. In the other 14 cases the portmanteau test or the size of the average absolute error leads the X–11 ARIMA program to a rejection of all three models. In 7 cases each model is even deficient according to both criteria. The small number of acceptances contrasts sharply with the findings of *Dagum* [1980]. Of the 305 series she examined, 81% could be described adequately by one of the models from which the program selects. From a set of 150 series studied later, even 90% met the criteria.

The third column of Table 2 gives the identification of the models used by the MSX–program. Occasionally the MSX–program rejects our identification of the ARIMA models due to large outliers in the residuals. In these cases we have tried other similar identification[3] until one of them was accepted by the program.

5 The Seasonal Adjustment Methods

The identification of the ARIMA models of the previous section leads to two alternative versions of the X–11 ARIMA adjustment method to be investigated here, viz.:

(a) X–11 ARIMA–OWN uses our identification of the ARIMA models.

(b) X–11 ARIMA–AUTO uses the identification of the ARIMA models by the program itself. Of course, this option only leads to seasonal adjustment in the case the ARIMA model has been accepted by the program.

Besides, this study considers

(c) Burman's signal extraction (MSX)–method, with our identification of the ARIMA model as input. As we looked for alternative identifications when the original identification was rejected, this method finally produced seasonal adjustment for all series investigated.

As this study aims at comparing X–11 ARIMA and the MSX–method with the traditional Census X–11 method, we have also corrected all series with

[3] These identifications are combined with outlier-options that differ somewhat from the standard options of Census X–11 en X–11 ARIMA.

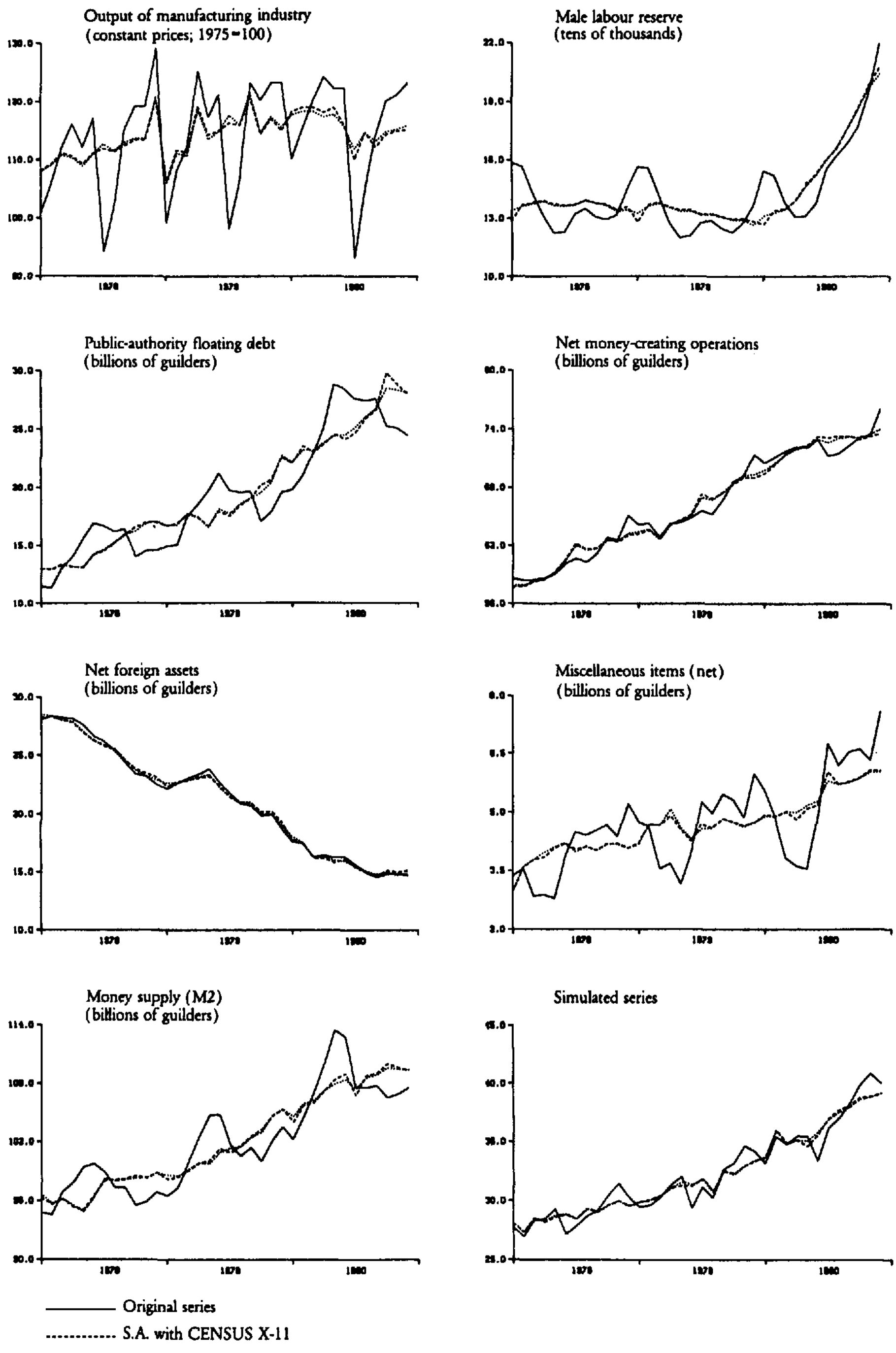


Chart 1. Original and seasonally adjusted series using CENSUS X–11 and X–11–ARIMA–OWN

Table 3. Average absolute percentage change

Method:	X-11 ARIMA OWN	X-11 ARIMA AUTO	MSX	Census X-11	Original series
Monthly series					
Output of manufacturing industry	1.83		1.79	1.83	6.38
Male labour reserve	2.99		2.58	3.25	8.69
Public authority floating debt	3.45		2.69	3.55	6.69
Net money creating operations	1.68	1.69	1.70	1.68	1.90
Net foreign assets	1.86		1.79	1.80	2.01
Miscellaneous items (net)	5.95	6.02	5.59	6.06	15.76
Money supply (M2)	1.07		1.09	1.10	1.57
Simulated series	1.74		1.78	1.75	3.52
Notes and coin	1.58	1.59	1.56	1.61	2.82
Demand deposits	1.11		1.19	1.15	1.76
Time deposits	3.22		2.96	3.26	4.08
Savings deposits with savings banks	0.78	0.78	0.73	0.79	0.77
Cost of living index	0.57		0.56	0.57	0.59
Unemployment in industry (excl. construction)	2.54	2.53	1.97	2.54	5.51
Unemployment in construction industry	7.05		5.68	7.21	20.76
Quarterly series					
Nominal GNP	2.71	2.71	2.73	2.73	4.65
National expenditure (value)	2.64	2.66	2.68	2.68	4.33
Industrial output	1.67	1.70	1.55	1.76	4.88
Total taxes	3.09	3.09	2.88	3.10	5.62
Interest charges on public debt	5.58	5.63	3.88	6.18	17.76
Public auth. fin. deficit on a transactions basis	nr		nr	nr	nr
Public auth. fin. deficit on a cash basis	nr		nr	nr	nr
Labour supply	0.21	0.21	0.20	0.21	0.32
Number of workers in man-years	0.26	0.26	0.26	0.26	0.32
Total unemployment	6.29		5.77	6.46	14.60
Total renumeration per industrial worker adjusted for absence due to sickness	2.49		2.47	2.51	2.51
Volume of investments (excl. ships and aircraft)	4.04	3.91	2.98	3.94	8.76
Domestic money supply	2.67	2.66	2.64	2.66	3.48
Changes in short-term bank lending	nr		nr	nr	nr
Net long-term operations of banks	nr		nr	nr	nr
Liquidity creation on behalf of public authorities	nr		nr	nr	nr
Financial assets of private sector	2.91	2.91	2.92	2.91	2.90
Exports	4.22	4.19	3.76	4.15	5.58
Imports	3.82	3.83	3.88	3.85	4.53

Explanatory note: nr indicates that calculation of this criterion is not relevant as the respective series sometimes obtain values close to zero.

(d) Census X–11
Use is made of the standard options: correction of extremes with sigma limits 1.5 and 2.5; no correction with prior daily weights and/or working-day regression; for X–11 ARIMA the same standard options were used where possible.

By way of illustration Chart 1 shows, for the first 8 monthly series, the original series for the period 1978:1–1980:12, together with the seasonally adjusted series produced by Census X–11 and X–11 ARIMA–OWN. Even though the chart deliberately relates to the last few years of the oberservation period only, it is clear that there is little difference in the results of the two methods of adjustment.

6 Results

Application of the criteria mentioned in section 3 to the four adjustment methods yields the following results:

(a) Average absolute percentage change
The results for the 34 series are shown in Table 3. The table confirms the expectation that the seasonally adjusted series are much smoother than the unadjusted series. This criterion does not reveal any major differences between the methods. Generally, MSX would appear to produce the smoothest seasonally adjusted series. For series with values close to zero, percentage changes may become very large and therefore the criterion value for those series have been omitted from the table.

(b) Orthogonality
The results for this criterion are given in Table 4. In most cases the seasonal component and the seasonally adjusted series seem to be virtually orthogonal; the only significant correlation coefficient at the 5% significance level appears in the series of unemployment in construction industry. Here, there is little difference between the methods of adjustment as well. The largest differences between the methods appear in the monthly series for the male labour reserve and the quarterly series for net long term operations of banks, where MSX proves least suitable.

(c) Idempotency
Table 5 gives the results for this criterion. The table shows that in most cases the criterion value is below one, indicating less than 1% residual seasonality in the adjusted series. Consequently, the methods of seasonal adjustment considered here are highly idempotent. A few large values occur in those cases where the original series does not display a clear seasonal pattern. Although the criterion values reveal slight differences between the adjustment methods, these differences are scattered such that the idempotency criterion hardly discriminates between the methods.

Table 4. Orthogonality

Method:	X-11 ARIMA OWN	X-11 ARIMA AUTO	MSX	Census X-11
Monthly series				
Output of manufacturing industry	0.03		0.03	0.04
Male labour reserve	-0.06		-0.12	-0.08
Public authority floating dêbt	-0.08		-0.07	-0.10
Net money creating operations	-0.01	0.00	0.00	-0.01
Net foreign assets	0.01		0.03	0.02
Miscellaneous items (net)	0.04	0.05	0.04	0.05
Money supply (M2)	-0.02		-0.01	-0.02
Simulated series	0.05		0.04	0.05
Notes and coin	0.00	0.00	0.01	-0.00
Demand deposits	0.02		0.01	0.02
Time deposits	-0.02		0.07	-0.03
Savings deposits with savings banks	0.01	0.01	0.02	0.00
Cost of living index	0.00		-0.00	-0.00
Unemployment in industry (excl. construction)	0.02	0.02	0.02	0.02
Unemployment in construction industry	-0.23		-0.27	-0.27
Quarterly series				
Nominal GNP	0.06	0.06	0.06	0.06
National expenditure (value)	0.05	0.06	0.06	0.06
Industrial output	0.07	0.07	0.06	0.07
Total taxes	0.05	0.05	0.06	0.05
Interest changes on public debt	-0.00	0.01	0.02	-0.03
Public auth. fin. deficit on a transactions basis	-0.01		-0.03	-0.04
Public auth. fin. deficit on a cash basis	0.00		-0.06	-0.02
Labour supply	0.01	0.01	0.00	0.02
Number of workers in man-years	-0.03	-0.04	-0.04	-0.04
Total unemployment	-0.04		-0.11	-0.04
Total renumeration per industrial worker adjusted for absence due to sickness	0.01		-0.01	-0.01
Volume of investments (excl. ships and aircraft)	0.01	0.04	0.03	0.04
Domestic money supply	-0.04	-0.04	-0.03	-0.04
Changes in short-term bank lending	-0.00		0.10	0.06
Net long-term operations of banks	0.07		-0.17	0.02
Liquidity creation on behalf of public authorities	0.09		0.08	0.03
Financial assets of private sector	-0.06	-0.06	-0.06	-0.05
Exports	0.00	0.02	0.00	0.02
Imports	0.03	0.03	0.05	0.03

Table 5. Idempotency

Method:	X-11 ARIMA OWN	X-11 ARIMA AUTO	MSX	Census X-11
Monthly series				
Output of manufacturing industry	0.26		0.43	0.23
Male labour reserve	1.27		0.65	1.23
Public authority floating debt	0.97		0.63	0.97
Net money creating operations	0.16	0.15	0.28	0.10
Net foreign assets	0.31		0.35	0.21
Miscellaneous items (net)	0.75	0.78	0.91	0.65
Money supply (M2)	0.15		0.23	0.11
Simulated series	0.15		0.35	0.14
Notes and coin	0.27	0.26	0.33	0.24
Demand deposits	0.13		0.25	0.10
Time deposits	0.75		1.03	0.61
Savings deposits with savings banks	0.10	0.10	0.03	0.10
Cost of living index	0.04		0.05	0.04
Unemployment in industry (excl. construction)	0.79	0.79	0.28	0.78
Unemployment in construction industry	2.57		1.63	2.42
Quarterly series				
Nominal GNP	0.13	0.12	0.29	0.15
National expenditure (value)	0.15	0.18	0.26	0.09
Industrial output	0.16	0.19	0.27	0.18
Total taxes	0.13	0.13	0.12	0.20
Interest charges on public debt	0.78	0.80	0.25	0.52
Public auth. fin. deficit on a transactions basis	6.32		2.64	6.51
Public auth. fin. deficit on a cash basis	5.25		1.56	7.60
Labour supply	0.03	0.02	0.02	0.02
Number of workers in man-years	0.01	0.01	0.01	0.01
Total unemployment	0.89		0.19	0.90
Total renumeration per industrial worker adjusted for absence due to sickness	0.07		0.11	0.08
Volume of investments (excl. ships and aircraft)	0.17	0.20	0.23	0.18
Domestic money supply	0.11	0.11	0.15	0.10
Changes in short-term bank lending	-1.54		8.65	-6.54
Net long-term operations of banks	15.64		-9.12	7.90
Liquidity creation on behalf of public authorities	7.90		152.77	13.35
Financial assets of private sector	0.06	0.05	0.05	0.05
Exports	0.23	0.22	0.17	0.19
Imports	0.23	0.21	0.49	0.15

(d) Residual white noise

The portmanteau test is used to check whether, after seasonal adjustment, the irregular component represents white noise. Table 6 shows that this criterion is seldom met. In order to investigate the residual signal in the random component further, we have computed both the first order and the 12th or 4th order autocorrelation.

A remarkably large number of significant negative first order autocorrelations shows up especially in the case of the quarterly series. The significant 12th or 4th order autocorrelations are less numerous but yet a sheer number of irregular components displays seasonality according to this test statistic. This result is the more surprising as according to Table 5 the methods are largely idempotent. Apparently the residual seasonality in the irregular component, although being significant, is small.

As regards to the MSX–method, it should be noted that this method deliberately does not always meet the requirement of the irregular component being white noise. This is, for example, the case when so called top heavy ARIMA models are specified. These are ARIMA models with MA–parameters of a higher order than the AR–parameters. Then the decomposition of the MSX–method yields a MA–process for the irregular component instead of white noise.

Indeed, the results of Table 6 reveal in the case of the monthly series that a significant (negative) first order autocorrelation occurs more often with MSX than with the other adjustment methods, albeit that we did not identify many top-heavy models. However, in the case of the quarterly series the first order autocorrelation of the irregular component is significantly negative for almost all series when adjusting with Census X–11 or with both X–11 ARIMA variants. Here, MSX seems to perform even somewhat better.

In sum it may be concluded from Table 6 that the seasonal adjustment methods studied do not meet very well the criterion that the random component is white noise.

(e) Stability

In order to assess the stability of the estimates of the seasonal components, five different runs have been carried out for each series and each adjustment method. In all runs the same year is used as a base, but in each new run one year of the series is added as compared with the previous run, so as to simulate an annual addition of new data[4]. The value of the stability criterion indicates to what extent the seasonal adjustment of prior years changes when new data are added. A zero criterion value would mean no change at all and hence perfect stability. The results for all common years in the period of five years and for the last common year are given for the 4 adjustment methods in Table 7 (for the formal definitions we refer to Appendix B). The table shows that the changes are largest if only the revisions in the last year are regarded, as is to be expected. Additionally, all methods evi-

[4] Recent experience [see e.g. *McKenzie; Dagum/Morry*] suggests that concurrent adjustment, i.e. rerunning the adjustment program for each new observation, may improve the stability of the adjusted series. This procedure is not investigated here as it would involve too many computations.

Table 6. Residual white noise

Method:	X-11 ARIMA-OWN		X-11 ARIMA-AUTO		MSX		Census X-11	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Monthly series								
Output of manufacturing industry	32.2	-0.27*			38.8	-0.49*	27.8	-0.25*
Male labour reserve	44.9**	0.15			45.1**	-0.40*	88.1**	0.09
Public authority floating debt	42.2	-0.11			0.2	0.00	24.0	-0.06
Net money creating operations	57.2**	0.08	61.0**	0.10	59.4	-0.43*	35.7	0.04
Net foreign assets	18.1	0.04			1.6	-0.06	25.1	0.01
Miscellaneous items (net)	23.6	-0.03	18.3	-0.05	6.8	-0.04	15.1	-0.06
Money supply (M2)	37.1	-0.02			90.4	-0.58*	36.4	-0.09
Simulated series	38.6**	-0.03			42.7**	-0.19*	40.7**	-0.11
Notes and coin	14.0	0.04	14.2	0.07	0.2	-0.01	14.2	-0.01
Demand deposits	120.0	-0.34*			0.0	0.00	131.0	-0.35*
Time deposits	35.6**	0.05			109.0	-0.66*	37.6	0.11
Savings deposits with savings banks	73.4**	0.33*	75.7**	0.31	6.0	-0.10	74.9**	0.21*
Cost of living index	15.3	-0.03			41.7	-0.49*	15.3	-0.05
Unemployment in industry (excl. construction)	67.6**	0.10	65.8**	0.10	26.6	-0.23	62.9**	0.16
Unemployment in construction industry	66.3	0.44*			74.1**	-0.42*	75.6	0.35*
Quarterly series								
Nominal GNP	25.8	-0.63*	26.3	-0.64*	5.7	-0.13	22.7	-0.59*
National expenditure (value)	29.3**	-0.45*	33.4**	-0.53*	26.9**	-0.57*	20.2**	-0.45*
Industrial production	17.0	-0.50*	20.3	-0.52*	28.7**	-0.50*	16.5	-0.51*
Total taxes	14.2	-0.40*	13.3	-0.37*	19.6**	-0.30*	10.4	-0.35*
Interest charges on public debt	9.5	-0.34*	10.9	-0.38*	33.7**	-0.53*	28.8	-0.65*
Public auth. fin. deficit on a transactions basis	20.3	-0.58*			0.5	-0.06	11.1	-0.43*
Public auth. fin. deficit on a cash basis	9.1	-0.39*			22.1**	-0.40*	21.2	-0.63*
Labour supply	11.6	-0.46*	11.9	-0.45*	10.2	-0.34*	10.0	-0.40*
Number of workers in man-years	15.2	-0.39*	13.5	-0.35*	0.1	-0.02	4.2	-0.19
Total unemployment	15.2	-0.53*			56.1**	-0.69*	5.0	-0.22
Total renumeration per industrial worker adjusted for absence due to sickness	18.0	-0.58*			20.5	-0.57*	15.4	-0.54*
Volume of investments (excl. ships and aircraft)	17.5	-0.54*	26.0	-0.64*	12.6	-0.50*	25.0	-0.63*
Domestic money supply	27.3	-0.61*	24.6	-0.57*	23.0	-0.23	22.5	-0.55*
Changes in short-term bank lending	6.0	-0.31*			10.5**	-0.27	13.8	-0.51*
Net long-term operations of banks	16.4	-0.47*			6.5	0.31*	19.9	-0.51*
Liquidity creation on behalf of public authorities	33.8**	-0.70*			12.6**	-0.14	33.7	-0.72*
Financial assets of private sector	13.1	-0.46*	25.4	-0.63*	23.9	-0.62*	11.7**	-0.33*
Exports	16.8	-0.47*	16.1	-0.48*	53.0**	-0.56*	15.0	-0.43*
Imports	15.8	-0.44*	17.3	-0.46*	12.1	-0.40*	15.4	-0.45*

Explanatory note:
- Column (1) shows the portmanteau statistic for 12 autocorrelations ($\chi^2_{0.05}(12)=21.0$) in the case of the monthly series and for 4 autocorrelations in case of the quarterly series ($\chi^2_{0.05}(4)=9.49$)
- Column (2) shows the first order autocorrelation

- * means significant first order autocorrelation
- ** means significant 12th order, resp. 4th order autocorrelation

Table 7. Stability

Method:	X-11 ARIMA-OWN		X-11 ARIMA-AUTO		MSX		Census X-11	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Monthly series								
Output of manufacturing industry	0.25	0.87			0.21	0.79	0.21	0.61
Male labour reserve	0.28	0.95			0.19	0.42	0.50	1.52
Public authority floating debt	0.47	1.93			0.51	1.48	0.47	1.80
Net money creating operations	0.21	0.73	0.16	0.47	0.17	0.38	0.08	0.29
Net foreign assets	0.20	0.80			0.24	0.58	0.12	0.44
Miscellaneous items (net)	0.60	2.20	0.46	1.54	0.44	1.49	0.34	1.30
Money supply (M2)	0.13	0.45			0.12	0.26	0.09	0.28
Simulated series	0.18	0.74			0.11	0.23	0.11	0.41
Notes and coin	0.13	0.54	0.15	0.50	0.14	0.39	0.15	0.46
Demand deposits	0.08	0.32			0.06	0.11	0.07	0.21
Time deposits	0.25	1.04			0.32	0.94	0.32	1.21
Savings deposits with savings banks	0.07	0.24	0.06	0.23	0.30	0.70	0.07	0.22
Cost of living index	0.02	0.09			0.03	0.07	0.02	0.07
Unemployment in industry (excl. construction)	0.15	0.59	0.20	0.63	0.22	0.41	0.20	0.82
Unemployment in construction industry	0.64	2.92			1.17	2.74	0.61	2.24
Quarterly series								
Nominal GNP	0.20	0.60	0.20	0.28	0.11	0.28	0.06	0.24
National expenditure (value)	0.17	0.52	0.15	0.28	0.10	0.13	0.07	0.25
Industrial production	0.17	0.66	0.12	0.47	0.23	0.55	0.10	0.42
Total taxes	0.20	0.45	0.14	0.43	0.22	0.56	0.09	0.30
Interest charges on public debt	0.38	1.48	0.51	1.40	0.18	0.95	0.29	1.02
Public auth. fin. deficit on a transactions basis	1.09	2.86			5.23	3.59	0.64	1.28
Public auth. fin. deficit on a cash basis	-11.53	-59.12			-6.47	-50.87	-11.74	-45.81
Labour supply	0.01	0.05	0.01	0.04	0.02	0.04	0.01	0.03
Number of workers in man-years	0.01	0.04	0.01	0.03	0.02	0.03	0.01	0.02
Total unemployment	0.14	0.57			0.13	0.46	0.23	0.84
Total renumeration per industrial worker adjusted for absence due to sickness	0.05	0.21			0.14	0.41	0.04	0.15
Volume of investments (excl. ships and aircraft)	0.35	0.98	0.22	0.43	0.32	1.45	0.12	0.37
Domestic money supply	0.07	0.27	0.08	0.26	0.09	0.23	0.07	0.23
Changes in short-term bank lending	5.94	11.70			5.13	11.14	2.38	8.12
Net long-term operations of banks	-0.93	0.95			-7.62	-27.22	0.39	1.18
Liquidity creation on behalf of public authorities	-9.99	-71.55			-5.54	-47.21	-5.35	-24.52
Financial assets of private sector	0.04	0.13	0.03	0.09	0.04	0.14	0.03	0.07
Exports	0.27	1.00	0.14	0.39	0.13	0.77	0.11	0.39
Imports	0.21	0.86	0.19	0.51	0.21	0.39	0.11	0.41

Explanatory note: – Column (1) gives the criterion value for all common years of the five year period investigated
– Column (2) gives the criterion value for the latest common year

dence instability, which means that they all lead to revisions in the seasonally adjusted series. In terms of stability, notably Census X–11 produces good results, which is all the more remarkable considering the fact that X–11 ARIMA is developed with the very aim of obtaining a more stable adjustment compared with Census X–11. Thus, our study does not show any distinct improvement in this respect. It is noticeable that in most cases where the automatic option in the X–11 ARIMA program is operational, this method appears to be more stable than when using our own identification of the ARIMA model[5].

(f) Estimation errors of simulated series
The inequality coefficients of Table 8 show that the various methods of seasonal adjustment do not display much difference in describing the 'true' seasonal component of the simulated series[6].

Table 8. Estimation errors of simulated series

Method	Inequality coefficient		
	total period	latest 3 years	latest year
X-11 ARIMA-OWN	0.530	0.434	0.530
MSX	0.541	0.692	0.784
CENSUS X-11	0.553	0.557	0.671

(g) Seasonality of the residual entry
According to Table 9, the F–value shows that the residual entry contains the most seasonality when the set of series has been corrected by means of the Census X–11 method[7]. It must be noted, though, that for none of the methods the seasonality in the residual entry is significant.

Table 9. Seasonality of residual entry (changes)

Method	F-value (test for residual seasonality)
X-11 ARIMA-OWN	2.048
MSX	1.523
CENSUS X-11	2.105

Explanatory note: The critical F-value at the 1% level for a 10-year series is 2.41.

[5] The differences for those series where the identification of the ARIMA model by the automatic option is the same as our own identification, are due to a divergency in parameter estimates.

[6] As the automatic option in X–11 ARIMA did not yield a satisfactory model for the simulated series, X–11 ARIMA-AUTO is not considered here.

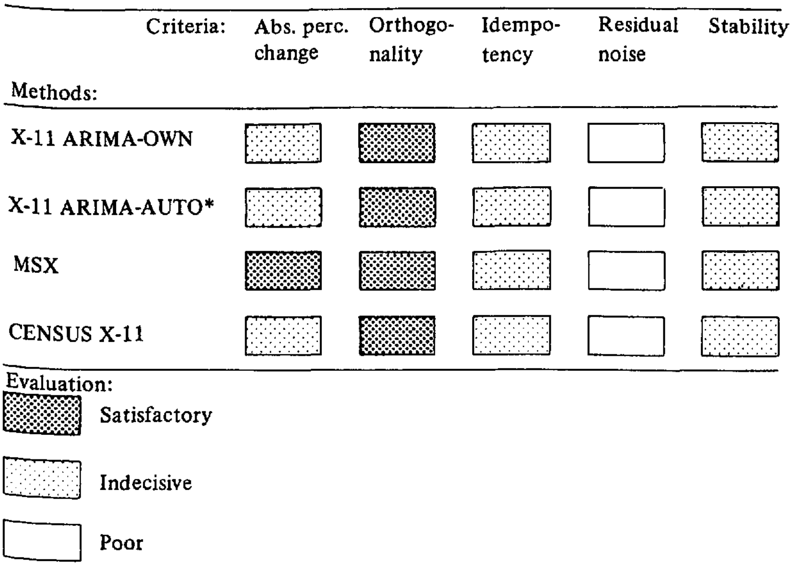
[7] Again, X–11 ARIMA-AUTO is not considered as no adequate models were found for the total and some component parts.

7 Conclusion

This study compares, on the basis of a number of pragmatic criteria, the Census X–11 method of seasonal adjustment with two variants of the X–11 ARIMA method and with Burman's signal extraction method. The difference between the variants of X–11 ARIMA relates to the identification and estimation of the ARIMA models used for extrapolating the series to be adjusted. In this way the sensitivity of this method to the choice of the ARIMA model is investigated. Whereas X–11 ARIMA constitutes a modification of Census X–11, Burman's signal extraction method yields a decomposition on the basis of an adequate ARIMA model of the series.

Table 10 summarizes the performance of the adjustment methods with respect to five criteria. Generally, Census X–11 and the X–11 ARIMA variants show few qualitative differences.

Table 10. Summarized assessment of the seasonal adjustment methods by single criteria



* This correction method could be applied to only 50% of the series investigated.

This is not suprising for the criteria regarding smoothness, orthogonality, idempotency and residual noise, since the intended improvement of X–11 ARIMA over Census X–11 relates solely to the estimate of the seasonal pattern in the most recent observations. Extrapolating the series with ARIMA models tries to improve the description of this seasonal pattern, so that addition of new data requires smaller revisions of the existing seasonally adjusted figures. Consequently, X–11 ARIMA should perform better than Census X–11 in respect of stability. However, our results do not conform to this assumption.

This result is somewhat at variance with the findings by others in similar comparative studies [e.g. *Newbold/Thury*, 1984a, b] where model based techniques seem to outperform the rigid application of filters by Census X–11. A close look at our results suggests that model based techniques are superior for those series where the ARIMA–models are stable and yield good predictions. In our study this is the case for the monthly series of the male labour reserve. Here, Census X–11 yields implausible month to month changes in the adjusted series at the end of each year and MSX in particular performs very well with respect to stability as compared with Census X–11[8]. However, on the whole the ARIMA–models for the series investigated by us show little stability and a poor predictive performance thus not justifying the sophistication of the model based techniques.

It is noticeable that the automatic option in the X–11 program, which selects an ARIMA model from three possible alternatives, yields an adequate model and hence performs seasonal adjustment for only 50% of the series investigated by us. This percentage is much lower than *Dagum* [1978] reports for her experiments. Hence we advocate an own identification of the ARIMA model before applying X–11 ARIMA.

According to our criteria, Burman's signal extraction method appears to be of the same quality as Census X–11 and X–11 ARIMA. The restrictions on the order of the parameters that the MSX–program imposes, proves to be not much of an impediment for the identification of an adequate ARIMA model. On the other hand, the criteria on the validity of the decomposition quite often reject the model selected at first instance and lead to a search for alternative specifications. This may make application of the MSX–method rather time-consuming.

Appendix A: Description and sources of data

Monthly series	Source
1. Output of manufacturing industry	CBS[1]
2. Male labour reserve	CBS[2]
3. Public authority floating debt	DNB, QS
4. Net money creating operations	DNB, QS
5. Net foreign assets	DNB, QS
6. Miscellaneous items (net)	DNB, QS
7. Money supply (M2)	DNB, QS
8. Simulated series	FKV
9. Notes and coin	DNB,QS
10. Demand deposits	DNB, QS
11. Time deposits	DNB, QS
12. Savings deposits with savings banks	DNB, QS

[8] Incidentally *Newbold* and *Thury*, in their comparative studies, concentrate on (Austrian) (un)employment series.

13. Cost of living index	CBS[1]
14. Unemployment in industry (excl. construction)	CBS[1]
15. Unemployment in construction industry	CBS[1]

Quarterly series

1. Nominal GNP	DNB, KC
2. National expenditure (value)	DNB, KC
3. Industrial output	DNB, KC
4. Total taxes	DNB, KC; DNB, DM
5. Interest charges on public debt	NA
6. Public auth. fin. deficit on a transaction basis	DNB, KC; DNB, DM
7. Public auth. fin. deficit on a cash basis	DNB, KC; DNB, DM
8. Labour supply	NA; DNB, KC; DNB, DM
9. Number of workers in man-years	NA; DNB, KC; DNB, DM
10. Total unemployment	NA; DNB, KC; DNB, DM
11. Total renumeration per industrial worker adjusted for absence due to sickness	NA; DNB, KC; DNB. DM
12. Volume of investments (excl. ships and aircraft)	DNB, KC
13. Domestic money supply	DNB, QS; DNB, DM
14. Changes in short-term bank lending	DNB, QS
15. Net long-term operations of banks	DNB, QS; DNB, DM
16. Liquidity creation on behalf of public authorities	DNB, QS; DNB, DM
17. Financial assets of private sector	DNB, QS
18. Exports	DNB, KC
19. Imports	DNB, KC

Explanation of symbols:	CBS[1]	: Central Bureau of Statistics: Statistical Bulletin
	CBS[2]	: Central Bureau of Statistics: Monthly report labour market
	NA	: Central Bureau of Statistics: National Accounts
	DNB, QS	: De Nederlandsche Bank N.V., Quarterly Statistics
	DNB, KC	: *De Nederlandsche Bank N. V.*
	DNB, DM	: The Netherlands Bank: Internal database for macro-economic modelling (with corrections for breaks in series)
	FKV	: *Fase, Koning and Volgenant*

Symbols

O	original series
S	seasonal component
SA	seasonally adjusted series
	a bar indicates the mean value over the observation period

t	time index
mq	12 for monthly data 4 for quarterly data
n	number of observations
r_k	autocorrelation of residuals
ly	latest year of the observation period used for seasonal correction
$n_{ly\text{-}1}$	number of obervations until year ly-1
S^{ly}	seasonal component obtained by seasonal adjustment over the observation period until year ly
$ST_{ly}^{ly\text{-}1}$	mean percentage change in seasonal components by extending the adjustment period from year ly-1 to year ly
$SLT_{ly}^{ly\text{-}1}$	mean percentage change in seasonal components for year ly-1 by extending the adjustment period from year ly-1 to year ly

Appendix B: Formulas for five criteria of this study

The criteria

(a) Average absolute percentage change

$$\frac{1}{n-1} \sum_{t=2}^{n} 100 \cdot \left| \frac{SA_t - SA_{t-1}}{SA_{t-1}} \right|$$

(b) Orthogonality

$$\frac{\sum_{t=1}^{n} (S_t - \bar{S})(SA_t - \overline{SA})}{\sqrt{\sum_{t=1}^{n} (S_t - \bar{S})^2 \sum_{t=1}^{n} (SA_t - \overline{SA})^2}}$$

(c) Idempotency

$$\frac{1}{n} \sum_{t=1}^{n} 100 \cdot \left| \frac{S_t}{SA_t} \right|$$

(d) Residual noise

$$n(n+2) \sum_{k=1}^{mq} \frac{r_k^2}{n-k}$$

(e) Stability (common years)

$$\frac{1}{4}\,(ST_{ly}^{ly\text{-}1} + ST_{ly\text{-}1}^{ly\text{-}2} + ST_{ly\text{-}2}^{ly\text{-}3} + ST_{ly\text{-}3}^{ly\text{-}4}) \text{ where}$$

$$ST_{ly}^{ly\text{-}1} = \frac{1}{n_{ly\text{-}1}} \sum_{t=1}^{n_{ly\text{-}1}} 100 \cdot \frac{|S_t^{ly} - S_t^{ly\text{-}1}|}{O_t}$$

Stability (latest year)

$$\frac{1}{4}\,(SLT_{ly}^{ly\text{-}1} + SLT_{ly\text{-}1}^{ly\text{-}2} + SLT_{ly\text{-}2}^{ly\text{-}3} + SLT_{ly\text{-}3}^{ly\text{-}4}) \text{ where}$$

$$SLT_{ly}^{ly\text{-}1} = \frac{1}{mq} \sum_{t=n_{ly\text{-}2}}^{n_{ly\text{-}1}} 100 \cdot \frac{|S_t^{ly} - S_t^{ly\text{-}1}|}{O_t}$$

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